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A Short Report of Unclassified Effort at the Naval Research Laboratory

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NAVAL RESEARCH LABORATORY
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ABSTRACT

For over forty-five years the Naval Research Laboratory, through its scientists and engineers, has been anticipating and serving the needs of the U. S. Navy. Situated within the District of Columbia the Laboratory today enjoys easy access to and contact with the central offices of all the governmental departments, and exerts a scientific influence well beyond the usually considered naval sphere of influence.

The scientific program is administratively divided into four Areas: Electronics, Materials, General Sciences and Oceanology; however, these Areas are not mutually exclusive–a quality which has allowed the Laboratory's scientific personnel to develop and apply their expertise along lines most appropriate to the Navy's interests, while maintaining a flexibility suitable for the application of their knowledge to nonmilitary problems.

Representative programs and accomplishments are discussed.

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PREFACE

As the Navy's corporate laboratory the Naval Research Laboratory has a responsibility for maintaining a research program which will furnish the scientific basis from which development efforts and, eventually, operational equipments or techniques will evolve. With its complement of scientific employees the Laboratory mounts an in-house research and exploratory development effort which successfully covers a wide spectrum of Navy interests and satisfies its corporate responsibilities.

This paper identifies only a portion of the Laboratory's unclassified work performed during 1968 and was originally prepared as a concise report, for the Chief of Naval Research, on NRL's scientific activity and accomplishments. The reader must bear in mind the fact that the major portion of NRL's effort is classified and, in general, is reported as separate items in the classified literature.

For those members of the Navy, and others, who are not entirely aware of the Laboratory's breadth of research involvement and accomplishments this publication should serve as a primer and a helpful ready reference.

The author has acted in the capacity of both author and editor. Much of the material was originally written after discussions with the bench workers, at least as much material, drawn from written documents of all kinds, was edited and reformed. A small amount represents open plagiarism–the original authors will recognize their own words. Since the list of scientists who should receive credit for their contributions is far too long to list here, I trust that my sincere "Thank You" will suffice.

Robert E. Seebold

A SHORT REPORT OF UNCLASSIFIED EFFORT AT THE NAVAL RESEARCH LABORATORY

MISSION

The mission of the Naval Research Laboratory is to conduct scientific research and development in the physical sciences and related fields directed toward new and improved materials, equipment, techniques, and systems for the Navy. In fulfillment of this mission, the Naval Research Laboratory.

1. Initiates and conducts scientific research and development of a basic and long-range nature in scientific areas of special interest to the Navy;

2. Performs scientific research and development for the Systems Commands and offices of the Navy and, where specially qualified, for the Defense Department and, in defense-related efforts, for other government agencies;

3. Provides to the Navy and its contractors standardized techniques and procedures for measurements and for the accurate calibration of standard instruments in areas of special Navy needs;

4. Furnishes scientific consultative services for the Navy and, where specially qualified, for the Defense Department and, in defense-related efforts, for other government agencies;

5. Provides to the Navy unbiased determination of performance characteristics of developmental and prototype devices through limited engineering test and evaluation services.

THE NAVAL RESEARCH LABORATORY

The Naval Research Laboratory is a field activity reporting to the Chief of Naval Research, who is directly responsible to the Assistant Secretary of the Navy for Research and Development. It was established in 1923 to ensure that advancements in science and engineering could be readily applied to the Navy's needs.

In order to satisfy the requirements inherent in its mission, the NRL research program has developed into a broadly based and coordinated effort in the physical, mathematical, and environmental sciences, in advanced engineering, and in naval analysis. In its investigations in broad scientific areas, in considering its findings for potential military application, and in furnishing to the Naval Systems Commands and Secretariat expert consultive services relating to science and military systems, NRL functions as the corporate laboratory of the Navy. In addition to providing a central focus for research and development within the Navy, the Laboratory, where uniquely qualified, provides support to other elements of the Department of Defense and agencies of the government.

The research and development program of NRL is financed by numerous sponsors. About 70 percent of the financial support is derived from major organizational units of the naval establishment (principally the Office of Naval Research, the Naval Ship Systems

Command, the Naval Electronic Systems Command, the Naval Air Systems Command, and the Naval Ordnance Systems Command); approximately 20 percent derives from Defense Department agencies, including the Army, the Air Force, the Advanced Research Projects Agency, and the Defense Atomic Support Agency; and the remainder is funded by such other governmental agencies as the Atomic Energy Commission and the National Aeronautics and Space Administration. The research program budget for the fiscal year 1968 was 86 million dollars.

The Laboratory is organized into three principal departments: the Office of the Director, the Support Services Department, and the Research Department. Headed by Dr. Alan Berman, Director of Research, the Research Department is composed of four major areas: Electronics, Materials, General Sciences, and Oceanology, with each area headed by an Associate Director of Research. Within this framework are grouped the sixteen scientific divisions, a special studies group and a number of smaller laboratory and office units.

Located on the east bank of the Potomac River in southwest Washington, D. C., the main site of the Laboratory occupies 126 acres and employs some 3600 civilians, of whom approximately 1900 are members of the Research Department (1250 scientific and professional, 650 technical support). Field activities are conducted at various locations which provide unique environments and facilities not available at the main site. Among these are the Chesapeake Bay Division, at Chesapeake Beach, Maryland; the Underwater Sound Reference Division, at Orlando, Florida; the Transducer Calibration Facility, on Seneca Lake, Dresden, New York; the Radio Astronomy Observatory, at Maryland Point, Maryland; communications research sites at Hybla Valley, Virginia, at Stump Neck, Maryland, at Brandywine, Maryland, and at Sugar Grove, West Virginia; communications and atmospheric physics research site at Waldorf, Maryland; an oceanographic research platform under the eastern span of the Chesapeake Bay Bridge, near Annapolis, Maryland; a space tracking facility at Blossom Point, Maryland; and a marine corrosion research facility at Key West, Florida.

Among the major research equipment and facilities available at the main site are a 75-Mev sector focusing cyclotron; a high-level radiation laboratory; a high-field (150 kilogauss) magnetic facility; Linear (60 Mev) and Van de Graaff (5 Mev) particle accelerators; and a 1-megawatt nuclear reactor. Additional major facilities include a number of large radio and radar antenna installations located at field sites. The Laboratory operates five aircraft equipped for research in radio, radar, and atmospheric physics. It has available for its use both oceanographic and experimental ship platforms.

In 1968 the dynamic physical growth of the Laboratory continued with the occupation of a major new building by space science researchers and with ground-breaking ceremonies heralding the beginning of work on a six-million-dollar chemistry building. Keeping ahead of this was the scientific activity. In order to facilitate and foster new lines of research and development a new Mathematics and Information Sciences Division was formed, two new laboratories, one for Structure of Matter and the other for Chemical Physics, were created, the Central Materials Research Staff was established, and a major portion of the Hudson Laboratories' acoustic research, formerly done under Office of Naval Research contract, was absorbed into the in-house program. These recent Research Department changes followed earlier actions, which had seen the Laboratory's absorption of the Underwater Sound Reference Laboratory and a major reorganization of the Laboratory itself to create a new Oceanology Area, composed of four active divisions and an Electronic Warfare Division.

RESEARCH AND ACCOMPLISHMENTS

Electronics

True to its name, the Electronics Area embraces a wide range of research and development devoted to and bordering on electrical and electromagnetic phenomena. The TIMATION program is representative of NRL's research and development effort which is keeping the U. S. Navy in the forefront of the world's military establishments.

In the fifty centuries before 1900, the practice of navigation progressed from latitude sailing to the celestial navigation method of determining both latitude and longitude (time) to one-mile accuracies with 15 pounds of reliable, non-jammable equipment. In the twentieth century, radio has improved the dissemination of time and the frequency of fixes in large areas but did not improve the accuracy of fixes materially. The doppler of the earth satellite provided the first significant improvement to deep water fixes but at the cost of a large computing facility. A need existed then for a system having an accuracy and a fix interval comparable to the doppler satellite, with improved convenience for the user.

The NRL-developed TIMATION satellite provides these virtues by means of a passive range measuring technique. Both the satellite and the navigation equipment contain stable oscillators. Signals from the satellite are compared to signals produced by the navigator's equipment, and a range to the satellite is inferred. By taking several ranges the measurement error can be found so both a position and a clock error can be determined. The clock error measurement serves as a means of transferring time to great accuracy. The data reduction process is almost identical to that used by celestial navigation.

An orbiting TIMATION satellite has been used to demonstrate the principle of the system as a navigation and as a time transfer device. A program has been initiated to use this device for experiments in time transfer between NRL and stations at the Richmond, Florida Naval Observatory Time substation, the Bureau of Standards station at Ft. Collins, Colorado, and stations in Texas and Alaska. Since the satellite location is a critical item in using it for navigation, predicted and post-satellite positions are furnished by the Naval Weapons Laboratory using TRANET data obtained from stations at the Applied Physics Laboratory of the Johns Hopkins University; Las Cruces, N.M.; Lasham, England; and Anchorage, Alaska.

The implications of this NRL program are that it appears possible to provide position and velocity fixes to a large spectrum of users. The cost can vary from perhaps $5000 for a small ship in which the navigator plots his position to $30,000 for an automatic system which gives continuous positions and velocities. The system can be used both with low altitude satellites and synchronous satellites. For low altitude satellites it would also provide the signal necessary for use by present doppler systems. Time transfer can be achieved of such quality as to allow synchronization of standards throughout the world for anticollision systems and other purposes.

With its complement of some 700 electronic and physical scientists, this Area devotes part of its effort to unclassified research in electron physics, including gas lasers. The carbon dioxide (CO_2) laser has been the subject of some NRL research and has been found to be the most efficient and highest power continuous-wave gas laser. Operating at 10.6 microns, which is a "window" in the atmosphere, it is an interesting and useful device; however, it normally requires a "flowing-gas" system in which the gas mixture is supplied from tanks for a single pass through the lasing tube. For uses in which portability is important, such a system is not very attractive due to the gas supply requirements.

NRL scientists recently developed a hermetically sealed CO_2 laser which has no external gas requirements and which can operate in excess of 1400 hours at an output power of 19 watts. This long life operation was attained through optimization of the gas fill such that an efficient laser mixture remains after chemical equilibrium is reached. The one-meter-long laser tube is within a factor of two of the efficiency of a flowing gas system. Further research and development should reasonably increase both the efficiency and operating life characteristics.

This accomplishment means that a very efficient, high-power CO_2 laser system may be designed for long-life mobile use without the restriction of providing an auxiliary gas supply.

Approximately six million dollars of the Area's 36-million-dollar budget is expended directly on radar research and development. The development of specific Navy radar systems has not been attempted in recent years; however, the NRL effort has involved the exploration of new radar concepts, the demonstrations of the feasibility of new ideas, and the research of system concepts which are applicable to enhancing the Navy's ability to fulfill its mission. While the scope of this effort is such that almost all of it falls under security classification, there is one recent unclassified accomplishment which may be mentioned here.

A complete understanding of the ionosphere and its effect on radar target detection is an ever-present goal, since ionospheric inhomogeneities give rise to phase and polarization fluctuations which interfere with the determination of the target cross section. Detection and accurate tracking of targets in the ionosphere require a catalog of predicted nontarget effects such as phase distortion, polarization rotation, and amplitude scintillation. Also, the effects of sporadic meteors and the radio aurora upon target discrimination must be understood.

Recent efforts at NRL have been directed toward the determination of an electron-density profile of the ionosphere during periods of severe magnetic disturbance. The effects of solar activity and solar zenith angle on the electron content and slab thickness of the ionosphere also have received considerable attention. These investigations have produced some interesting results.

A tremendous enhancement in the amount of Faraday rotation immediately follows the sudden commencement of a magnetic storm, after which there is a rapid decay in rotation and a very intense amplitude scintillation. The rotational enhancement corresponds to an apparent electron population increase of about 100 percent, which occurs over a time period of about an hour—a fantastic effect. The tentative conclusion is that gradient effects are responsible for a large fraction of the rotational enhancement. This conclusion is based upon data obtained from over 1500 hours of radio transmissions between April and August 1967.

On the basis of over 185 records of orbiting satellite transmissions at 137 MHz, which were obtained at the Randle Cliff radar site during the first eight months of 1967, a definite relationship has been established between the noontime solar zenith angle and the ionospheric electron content and associated slab thickness. Results of radar studies in which Echo II was used as the target have shown that at sunspot minimum the electron content is—on the average—independent of season, although slab thickness is much higher in summer than in winter. On the other hand, both content and slab thickness appear to be increasing functions of the noontime elevation of the sun during periods of moderate solar activity.

This type of information will be used in the forming of a more coherent picture of the ionosphere and its inhomogeneities. The end results should be more reliable radar systems having increased capability for target detection and identification.

Radio communication, navigation and propagation, and centralized electronic control are subjects of some of the research and development at the Naval Research Laboratory. As part of the radio program the Laboratory, in fiscal year 1968, developed one of the nation's outstanding facilities for the conduct of satellite communication and other microwave space research. Located at Waldorf, Maryland (with a similar facility at La Posta, California), the facility is equipped with a computer-controlled, parabolic, cassegrainian 60-foot antenna of the highest steering accuracy, speed and flexibility and of a quality permitting operation at frequencies higher than other antennas of similar size, a 25-kilowatt transmitter, an advanced, low-noise receiver, an on-line data processor, and the means to perform experiments of highest frequency precision and time control.

This facility was recently used as a satellite radio reception terminal to demonstrate for the first time the feasibility of transmitting very high quality pictures over a two-hop satellite radio circuit from Vietnam via the West Coast to Washington, D. C. Transmissions were made using Department of Defense (DoD) synchronous satellites at transmission rates of 720 kilobits per second, a rate many times higher than that possible with ionospheric radio transmissions which carry most of the DoD radio communications.

Electronic warfare-type research and development which is required in support of the Navys electronic warfare mission in the fields of space technology, intercept and signal processing, emitter location, and defensive electronic warfare is performed at NRL. As part of this effort the Laboratory has been the center of development of a new series of intercept, signal analysis, and direction finding equipments for U. S. Navy ships and aircraft which are now being deployed in Southeast Asia. These equipments feature new techniques, designed to enhance the capability of the fleet under combat situations.

In 1968 the Director of Navy Laboratories, in concert with the Chiefs of Naval Research and of Development, designated the NRL as lead laboratory for coordination of the Navy laboratories' research and development program in electronic warfare. The ultimate intent of this assignment is to develop, as a matter of urgency and vital military importance, an electronic warfare effectiveness in the Fleet commensurate and compatible with its command support and other weapons systems.

To discharge this responsibility the Laboratory will support the electronic-warfare management operations and responsibilities of Chief of Naval Development, Chief of Naval Research and Director of Navy Laboratories by developing a coordinated in-house exploratory development master program plan for electronic warfare having the flexibility to meet changing requirements, will continue to provide substantial direct Laboratory effort in electronic warfare, and will develop and maintain an active liaison with electronic warfare affected elements of the Navy both ashore and afloat.

Materials

Within this Area, there is now in progress a viable and diverse program ranging from chemistry through metallurgy to solid state physics. Current problems to which the Laboratory is giving particular attention in the chemical field are corrosion, reinforced plastics, fire prevention and extinguishment, aircraft carriers, fuel cells and life support in closed ecologies, and BW/CW defenses.

A recently developed biological-warfare decontamination technique, which requires only a few seconds and which is effective when used on fullv clothed persons, resulted from the latter effort. Nicknamed SLASH, for Self-Limiting Activated Solution of Hypochlorite, the treatment is based on the reasoning that hypochlorous acid is the germicidal component in hypochlorite solutions. Acting on this reasoning, the NRL researchers discovered that Bacillus subtilis var. niger spores are destroyed by hypochlorous acid in five seconds at room temperature. Further research proved that by spray-mixing a hypochlorite solution with a citric acid solution, a hypochlorous acid solution could be prepared, in the spray, which would perform its decontamination role in seconds and then neutralize itself by the self-contained neutralizer. This spray process has been proven to be 99.9 percent effective on cotton, on cotton-nylon, and on woolen clothing as well as on masks, on shoes, and on bare skin.

The new development is compatible with the Shipboard Toxicological Operational Protective (STOP) system concept and should eliminate the need for handling and processing contaminated clothing in the laundry of a STOP-equipped ship. Since the destructive effects of hypochlorite have been reduced to levels which will be negligible in most situations, the variety and sensitivity of equipment which can be decontaminated is markedly increased, and the possiblity of compromising the STOP-equipped ships is reduced.

Closed-ecology life support efforts have centered on the atmospheric habitability of submarines. At present emphasis is being devoted almost exclusively to nuclear powered submarines, although an increasing effort is being applied to SeaLab and other tasks of the Deep Submergence Systems Project. Some past and expected future effort has been and will be directed toward space capsule atmospheres.

Problems caused by excessive methyl chloroform or chlorinated hydrocarbons, which, upon passing through submarine CO-H_2 burners, decompose into corrosive and possibly toxicological products have been the subject of extensive investigation. A method has now been devised for the detection of strong-acid vapors in the parts-per-million (ppm) range using pH indicator paper disks. The disks are impregnated with meta-cresol purple and combined with a color comparison chart into a kit available for use in the Fleet in tandem with a sampling pump already available on each submarine.

A rapid-scanning mass spectrometer has been coupled with a capillary gas chromatograph at NRL to provide an enhanced laboratory method for analysis of atmospheres containing contaminants. The capillary chromatograph uses an extremely small sample, which is then separated into fractional components and subsequently fed into the mass spectrometer, where the mass spectrum is scanned in less than 1.5 second; however, the entire analysis takes additional time. Volatiles from an adhesive were recently examined with the system and spectra obtained for 50 components in less than one hour. Additional applications are planned, including the checking of many materials used in submarines and space capsules, for off-gassing properties in appropriate environments.

The NRL Total Hydrocarbon Analyzer has been extensively field tested at sea and is slated to be produced commercially for issue to all nuclear submarines. The instrument fulfills a need to monitor the atmosphere for possible contaminants, which are mainly hydrocarbon in nature, and can be used to detect certain other potentially toxic or corrosive components in the atmosphere. It may possibly also be used to determine the extent of saturation of the main carbon filter in the ship's ventilating system.

Another device intended to determine the extent of saturation of the main carbon filter has been experimentally demonstrated in the laboratory. The device depends on the principle that the water content of an adsorbent charcoal at constant relative humidity is related to its residual adsorptive capacity for organic contaminants. A closed-loop apparatus was designed and evaluated with 14 charcoals from submarine main carbon filters; in general, the water contents were proportional to the known residual adsorptive capacities. However, there are certain limitations to its use in the submarines at present, and additional work appears necessary to circumvent or eradicate the limitations.

A nuclear-magnetic-resonance (nmr) spectroscopy method has been developed for the determination of the organic loading of carbons as well as certain qualitative information about specific contaminants. It is faster than the steam desorption technique for determining carbon loadings, and the results are comparable. Use of the method is restricted to shore-based installations, because of the size and weight of the spectrometer, and to organic compounds which contain hydrogen. The method will probably often be used by NRL in future analyses of main carbon-filter charcoals.

Recent work by NRL electrochemists has indicated that the passivation of the hydrogen oxidation reaction on platinum in acid solution is caused by anion adsorption with the major effect being due to a poisoning of catalytically active sites. Following this, further effort was undertaken to relate these findings to both platinum and iron electrodes in alkaline solution.

Using a rigorously controlled high-purity closed system, the researchers discovered some remarkable differences in catalytic and electrochemical behavior from literature-recorded expectations. The differences in catalytic behavior of the two metals were great, and their passivation behavior strongly reflected the differences in metallic properties and the influence of anion adsorption. No significant corrosion of iron was found, and iron was a far better catalyst for the hydrogen oxidation reaction at all anodic potentials. Anion poisoning of catalytically active sites on the iron was much less pronounced than on platinum. This means that anion adsorption has less effect on the surface states of iron than on platinum and that certain fuel cell applications may be possible.

In the metallurgical field the Laboratory conducts research, development, and evaluation into the physical, mechanical, chemical, and structural aspects of metals. Some recent research indicated that copper is a critical constituent in radiation-sensitive reactor pressure vessel steels and weldments. Comparison examinations of low-copper (less than 0.1 percent) alloys and of higher copper (greater than 0.25 percent) content alloys demonstrated significantly higher rates of embrittlement, after neutron irradiation at 295°C, for the higher copper content steels. Since copper is not metallurgically significant to pressure vessel plate and welds, its elimination from commercially produced steels could have far-reaching positive effects upon controlling or minimizing neutron-induced embrittlement in reactor components.

As part of the metal physics program, NRL scientists have obtained the first direct measurements of solid-liquid interfacial free energy in metals. Based on a recent NRL discovery that the equilibrium form of a pure metal bicrystal boundary in contact with its melt can be studied at magnifications above 100,000X with the electron microscope, these measurements will permit a more critical assessment of a number of theories concerning the interaction of solid and liquid metals, particularly those regarding liquid-metal embrittlement, grain-boundary melting, and nucleation and growth of metals from melts.

In another bit of unclassified research, Laboratory scientists have developed a new technique for improving the magnetic reversal behavior of thin permalloy films. It is well known that permalloy films are useful as memory storage devices in high-speed digital computers; however, their usefulness as binary logic elements depends directly on the fraction of magnetization vectors that undergo a magnetization reversal by coherent rotation. With this new technique, the magnetic switching behavior is improved markedly by exposing Permalloy films to high dosages (2×10^{17} particles/cm^2) of 2 Mev helium-3 particles, while simultaneously applying a 500-oersted magnetic field parallel to the predetermined average easy-axis direction of the films. During irradiation the temperature of the films in maintained at 60°C.

The results of radiation exposures in magnetic fields reveal that the magnetic parameters which characterize the degree to which the magnetization vectors of the film rotate noncoherently, the so-called easy-axis dispersion, $\alpha 90$, and the anisotropy field homogeneity, $\Delta 90$, are reduced considerably. Decreases in $\alpha 90$ and $\Delta 90$ as much as 60 percent were common. This method for improving the magnetic switching behavior of

Permalloy films is far more effective than the usual thermal magnetic annealing treatments which have been used for many years.

Solid state research activity at NRL covered a wide range of interests in fiscal year 1968. Areas under investigation include optical and electronic properties, magnetism, radiation damage, and cryogenics as parts of a comprehensive fundamental and applied research program in the physics of materials (metals, semiconductors, dielectrics, and glasses).

A large portion of these efforts revolves about optics, and optical frequency generation and detection. Researchers in the nonlinear optics field have obtained the first experimental evidence that index matching may be achieved in a nonlinear optical process by the introduction of anomalous dispersion.

Maximum efficiency for conversion of laser radiation to a higher frequency harmonic is obtained in a nonlinear medium when the index of refraction of the laser wave is equal to that of the harmonic. For normal dispersive media, the index of refraction at the harmonic frequency is greater than that at the fundamental one. Heretofore, index matching has only been achieved in birefringent crystals. Recent NRL experiments have shown that the index of refraction of a medium can be suitably altered by the anomalous dispersion of an additive in the medium so as to produce the index matched condition.

The NRL experiment involved the generation of the optical third harmonic of the neodymium laser line at 1.06 microns. The third harmonic medium was a liquid, hexafluoroacetone sesquihydrate, with the dye fuchsin red introduced for matching. A laser beam of approximately one megawatt per square centimeter, passing through a 0.05-centimeter optical cell containing this dye-solvent combination generated 30 microwatts of third harmonic radiation at 353 millimicrons despite the presence of appreciable attenuation introduced by the medium at the third harmonic frequency (the absorption coefficient is 670 cm^{-1} at the critical dye concentration for matching).

Current research is directed to increasing the efficiency of this new method of third harmonic generation. This principle may now be applied to other interesting spectral regions in the harmonic generation process, and also it may be useful in nonlinear optical processes other than harmonic generation.

The use of photochromic materials (materials capable of changing color by exposure to light) is seriously being considered as a means of achieving extraordinarily large storage capacities for electronic computers. Instead of using magnetic cores as bits and equating the digital information to their two states of magnetization, the new optical technique involves equating the information to the presence or absence of coloration in extremely small segments of a material. The functions of writing, erasing, and reading would all be performed with laser beams; however, the major obstacle to actually using such a system is the apparent difficulty in finding a photochromic material which will withstand fatigue, be reversible for an indefinite period of use, and allow the stored information to be read in a nondestructive manner.

At the Naval Research Laboratory, a material has been found which may overcome these difficulties. It is simply an alkali halide crystal containing atomic-sized defects known as color centers. A certain type of center, the M_A, is anisotropic and absorbs plane-polarized light strongest for a particular orientation. Reorientation can be achieved by excitation with light of certain frequencies, and total alignment along a single lattice direction is possible. Binary information, readable nondestructively at other frequencies, might take the form of deviations from a state of total alignment in a given direction. The crystal would need to be kept at low temperatures (200°K), where the processes would be entirely reversible and fatigue would be inconsequential, but a relatively high storage capacity of 10^8 bits per square centimeter of active crystal surface should be achievable.

General Sciences

Space sciences, plasma, nuclear and cosmic ray physics, and mathematics are the general fields of research within the General Sciences Area. Following an active research and development program covering upper air physics, astronomy, and astrophysics, full use is made of rockets and satellites in order to obtain information on radiation from the sun and celestial sources and to study the composition and behavior of the ionosphere. Radio telescopes are used for astronomical observations. Results from these programs, such as SOLRAD which is nationally known, are of importance to radio communications, to utilization of the space environment, and to the fundamental understanding of natural radiation phenomena.

SOLRAD satellites are constructed in-house by NRL using special instrumentation, fabrication facilities, and environmental test facilities shared by other space projects. The satellites are tracked and commanded from a single Laboratory station located at Blossom Point, Maryland, with telemetry data being processed by the Data Operations Center located within the Laboratory. On a near real-time basis, reports of solar x-ray, ultraviolet, and particle activity have been provided as disturbance warnings to various research and operational activities; i.e., National Aeronautics and Space Administration, the Environmental Science Services Administration, the Air Force, Naval Communications Command, and NRL propagation and communication projects.

From the space sciences program, which is in the forefront of developing technology, have come such significant contributions as night (low-light-level) vision, microcircuitry, and image converter devices. The research, using these and other devices, produces information of significant cosmological importance. For instance, an experiment performed from an Aerobee rocket launched during 1968 has produced evidence for the existence of a thin, hot, intergalactic gas. The experiment represents the newest phase in the investigation of background radiation, which has important implications for cosmological models of the universe.

The evidence for intergalactic gas was obtained through the use of x-ray proportional counters of two types. One, sensitive to x rays in the 0.25 kev range (44 to 60 A wavelength), detected a flux coming from the galactic pole, and hence from outside the galaxy, that may be due to thermal radiation from a hot intergalactic plasma.

It was essential, however, to examine a second possibility. A higher energy x-ray background spectrum is known to exist. This is often attributed to inverse-Compton action of relativistic cosmic-ray electrons on 3°K infrared background photons. The second x-ray detector provided a pulse-height-analyzed record of this x-ray spectrum in the poorly observed region from 1.5 to 8 kev. The results showed that downward extrapolation of the higher energy spectrum would fall about one order of magnitude below the observed intensity at 0.25 kev, depending on the assumption one makes concerning interstellar absorption of soft x rays. Thus, the soft x rays observed probably represent an independent source of x rays.

The existence of the intergalactic gas has considerable significance for cosmology. To provide the intensity observed at 0.25 kev and still not provide a significant signal at 2 kev, the temperature of the gas must be less than one million degrees, and have a density, if it is smoothly distributed, of 10^{-5} particles per cubic centimeter. This is the critical density for obtaining a closed, rather than open, universe, for while an open universe will expand forever, a closed universe will gradually slow its expansion to a stop and then fall inward until all the galaxies condense again to a fireball of matter and radiation.

Research in nuclear physics at the Naval Research Laboratory is made possible by the presence of outstanding major facilities. Theoretical and experimental programs in properties of nuclei, nuclear forces, nuclear reactions, shielding studies, x-ray and electron optics, and weapon-related research are combined in the broad-based basic and applied efforts. Facilities include a new 75-Mev sector focusing cyclotron, a 60-Mev Linac, a 1-megawatt reactor, a 5-Mev Van de Graaff accelerator, a 14-Mev neutron generator, and other particle accelerators and radiation sources.

Numerous applications have been derived during the past year from the strong base of nuclear science and technology developed at the Laboratory. The most important applications have been in the field of analysis of materials, not only for chemical composition but also for structure and spatial properties. New knowledge and instruments enabled us to utilize more fully the techniques of nuclear activation analysis, and to embark on programs of analysis by prompt nuclear reactions, surface analysis, isotopic analysis, neutron diffraction in vitreous materials, and ion implantation. Following are a few selected examples showing how the unique properties of nuclear reactions have been utilized in materials analysis this past year.

Certain impurities in rocket propellants can lead to undesirable radar reflection and absorption properties of the rocket exhausts. Analysis of these impurities has been developed by neutron activation using the NRL reactor. The improved reproducibility over chemical analysis and its nondestructive nature has led to the recommendation that this technique be used for quality control.

Many properties of materials, such as wetting, adhesion, contact potentials, etc., depend critically upon surface cleanliness. To help resolve some discrepancies, "clean" surfaces of gold and platinum were analyzed by direct bombardment with a helium-3 beam from the 5-million-volt Van de Graaff accelerator for traces of oxygen and carbon. By activation analysis with these charged particles about 20 atomic layers of oxygen and carbon were measured. Furthermore, the sensitivity of this technique was shown to be capable of detecting only one-thousandth of one atomic layer, thus the frontiers of surface "cleanliness" have been pushed down several orders of magnitude. Direct bombardment of crystals by heavy ions from the Van de Graaff have enabled scientists to understand better the mechanism for the production of color centers.

Fractionation of the calcium isotopes is expected in the shells of marine life. This fractionation can measure differences in temperature, salinity, and weather over recent and geological times if modern shells are compared with fossils. The newly installed NRL 75 Mev cyclotron has been used to provide a proton beam which can induce identifiable radioactivities in the different calcium isotopes, thus providing a means for studying isotope fractionation. The cyclotron, with its great versatility in accelerating various particles to preselected energies, provides NRL with a powerful tool for materials analysis, as well as for radiation effects studies with its high-intensity secondary neutrons.

For studies in oceanography, it is important to determine the presence of fluorine, bromine, and iodine in sea water. Radioactivation analyses for these have been made through nuclear reactions produced by high-energy x rays and neutrons from the NRL 60-Mev linear accelerator. The high-intensity pulsed radiation from this accelerator has also been used to study the radiation hardness of materials and components.

The first extracted alpha beam of the NRL isochronous cyclotron was achieved on February 12, 1968. This was preceded by extensive magnetic field measurements coupled with the development of computer progress to predict the operational parameters (knob settings) for the currents in the various coils needed to achieve an acceleration field. Ion orbital theory was used to calculate the proper magnetic field, and the necessary currents were obtained through linear programming techniques. Innovations introduced in the NRL programs include taking into account trim coil interdependence and the change of flutter parameters with trim coil currents, as well as first harmonic minimization and the influence of the beam extraction elements on the magnetic field. Internal beam studies have proven that the computational techniques developed provide correct trim coil currents for successful acceleration and extraction of the ions at full radius, thus eliminating the thousands of hours usually necessary for beam development.

Alpha beams have been accelerated over the full design range of 9 Mev to 90 Mev. Other ion beams will include protons with energies up to 70 Mev, deuterons up to 45 Mev, helium-3 up to 120 Mev, and various heavy ions with maximum energy depending upon the mass and charge state. The ion energies are variable from about 15 percent to 100 percent of maximum with an inherent energy spread of 0.4 percent. This energy spread can be reduced to 0.02 percent for precision experiments by an n=1/2, 9-foot radius, double-focusing analyzing magnet. High-intensity irradiations with the nonanalyzed beam are also possible.

The first experiment was performed with a 22-Mev proton beam, achieved by accelerating a negative hydrogen beam and then extracting this beam by passing it through a thin foil which stripped the electrons from the ions and thus reversed their radius of curvature. These energetic protons were used by the Rocket Spectroscopy Branch to study spectral deterioration in spectroscopic film produced by the radiation expected during Apollo space experiments.

With the excellent arsenal of nuclear "guns" at NRL, the valuable knowledge and experience of its scientists acquired through the basic research program, and the rapidly increasing interdisciplinary collaboration among its scientists, the unique analytical capabilities of nuclear techniques developing at NRL will have an important influence on many fields of science and technology in the Navy.

Plasma physics efforts at NRL include fusion physics, the generation and containment of high-temperature plasmas and electron beams, and high-power lasers. In conjunction with the space sciences research there is some work in laboratory astrophysics. The Laboratory, the University of Maryland, and Cornell University are presently engaged in a joint program of plasma physics research which significantly increases the scientific breadth of the participating institution and facilitates interaction of leading scientists in the field.

A part of this cooperative program, which brings together researchers and their interdisciplinary approaches to the solution of the many problems connected with laser research and development, has concerned itself with nonlinear optics and Raman experiments. The Laboratory effort in this area has been concentrated on high-brightness lasers and on the factors which affect laser performance. Design of lasers having a high degree of spatial uniformity and of frequency purity has been accomplished.

Recently the fine art of pumping a solid state laser has been advanced with a new high-intensity flash lamp designed and developed by a member of the Laboratory's scientific staff. This device is a coaxial gas discharge lamp and, in appearance, resembles a clear fluorescent lamp having a thicker diameter and a hollow center. Two cylindrical quartz tubes, one inside the other, surround the hollow center through which the laser material is placed. When the vacuum-tight space between the tubes is filled with a gas and an external current applied to electrodes at either end, the lamp produces a short-duration flash of extremely high intensity–approximately 100 times brighter than a conventional electronic flash lamp. By placing a third cylindrical tube around the lamp's outer perimeter, a liquid or gas coolant can be supplied.

Seeming simplicity of construction belies the improvement the lamp represents over previously used light sources. Because the new lamp completely envelops the laser material, it is now possible to completely and uniformly illuminate the material along its entire length.

Ruggedness of design allows the lamp to withstand extremely high currents which produce high light intensities in a very short time. Laser power output of a solid state material depends, in part, on intensity of the light source. Although the lamp was originally intended solely as a bright light source for pumping lasers, it has found applications in other instances where a short-duration, high-intensity flash is required.

Research in mathematical sciences at NRL is centered in the newly formed (fiscal year 1968) Mathematics and Information Sciences Division. This group of specialists is charged with the responsibility of determining the present and future needs of the Navy in mathematics and the computer-oriented sciences. In creating and maintaining the competence required to formulate and to meet these needs, effort is expended on research computation (i.e., data engineering and operations, analog computer programming and programming systems, and information retrieval); on mathematical physics, wherein mathematical concepts of physical phenomena are derived and where consultive mathematical services are available; and on information systems which deal with adaptive systems and systems simulations.

Of current interest to the Navy is the construction of a large sphere for use as a manned deep-submergence vehicle. The size of the sphere necessitates that it be built from many small components which, from a machinist's point of view, should have as much congruence and symmetry as possible.

NRL mathematicians recently completed a preliminary analysis of this problem, that of approximating the sphere by a particular class of convex polyhedra. The polyhedra in this class have a progressively increasing number of faces, and, as this number increases, the polyhedra more closely resemble a sphere, i.e., the dihedral angles formed at all edges approach 180 degrees, and the sum of the face angles at each vertex approaches 360 degrees. The relevance of this phase to the general problem is that it is possible to "project" the polyhedron onto a sphere whose center coincides with the centroid of the polyhedron, such that the vertices of the polyhedron are radially projected onto the surface of the sphere and connected by arcs of great circles. The spherical polygons thus formed are the components needed to construct the sphere. The question of the symmetry of these components is now undergoing study.

In a slightly different vein NRL mathematicians have been assisting Laboratory oceanographers who have been conducting an extended series of field tests to evaluate the probability of detecting a submarine under certain given conditions. The theory of the statistical design of experiments, and hence that of factor analysis, is not completely applicable here since, under field conditions, the experimenter must accept the values of environmental variables as they occur in nature. No arbitrarily prescribed levels may be chosen. Nevertheless, on the basis of several already-made field tests, a combination of statistical techniques is producing some useable conclusions pertinent to antisubmarine warfare activity.

Oceanology

Under the broad heading of oceanology the Naval Research Laboratory engages in programs dealing with underwater acoustics, ocean sciences, and ocean technology. Underwater acoustics includes sound generation, sound propagation, and signal physics, and is aimed, primarily, at acoustics applied to active sonar in antisubmarine warfare. The knowledge and techniques evolved are, in general, classified information which has broad application to other warfare missions.

Theoretical and experimental research programs in physical acoustics, in ocean acoustics, and in predictive oceanography, to develop theory and models of the interaction of acoustic fields with structures and the ocean environment, are combined with specialized programs in acoustical measurement theory and in development of electroacoustic transducers, measuring techniques and instrumentation. A major recent unclassified accomplishment resulting from the acoustic program has been the Laboratory development of a near-field method and equipment for calibration of large transducers.

The calibration of large transducers in the sonar systems of the size of the BQS-6 by the classical method of far-field techniques has been seriously inadequate, the principal cause being the requirement of a long base line between the transducer and the receiver hydrophone array to insure the completely developed formation of the far-field beam pattern of the transducer. The major difficulties of the conventional technique are establishment and stabilization of the mechanical base line and the masking effects of multiple acoustic paths. Recently efforts have been made by the Defense Research Laboratory and NRL to develop a near-field calibration technique. This technique proposes to effect a far-field environment, i.e., a plane-wave region in the immediate vicinity of the transducer under calibration.

Using an acoustic design based on a method invented and elaborated on by an NRL researcher, a physical realization of this design has been produced in the form of an amplitude-shaded planar array of 2500 acoustic elements in a square matrix with 8-inch spacing that will produce a plane-wave volume large enough to envelop a transducer of the BQS-6 size in front of the array. This array is unique in being the largest planar calibration array in the Navy designed to handle submarine sonar arrays as large as a 17-foot cube, in the frequency range of 1 to 6 kilohertz.

Studies on the completed array are currently in full progress both at NRL Underwater Sound Reference Laboratory, Leesburg, Florida, and at NRL Transducer Calibration Facility, Dresden, New York. Success is to be measured in terms of the volume of uniform acoustic pressure field developed by the array in its immediate vicinity. Measurements have shown a 22-foot diameter × 18-foot-deep plane wave volume whose uniformity is ± 2 decibels. Reduction of pressure field deviation to 1 decibel is the goal now receiving attention. Calibration of a 10-foot line hydrophone array in the 1- to 6-kilohertz range by this near-field array shows good agreement with the conventional far-field method.

These results show that the undersea technology capability of calibrating large sonar arrays by a rapid, economic, accurate, and error-proof procedure has been advanced by use of near-field research. The NRL Near-Field Calibrating Array will be used to render testing of prototype BQS-6 models expeditiously, and by saving time and money, will reduce lead time between available prototype and final submarine installation.

Ocean science oriented research includes studies of the physics, chemistry, geology, and biology of the oceans and is directed toward an improved understanding and use of the oceans as the major operating environment of the Navy. Such varied programs as the detection of submarines by nonacoustic means, weather instrumentation, cloud physics and atmosphere dynamics, and biophysical studies of the marine environment are interlocked so that the practical results lead to improvement in the design and effectiveness of naval equipment, materials, and systems.

Ice formation in clouds, a major factor in weather development and hence a strong influence on the operational efficiency of the Navy, has been investigated via a joint NRL-Australian program using observations from aircraft. It was found that columnar ice crystals were present in a maritime cumulus cloud having a cloud-top temperature of about -4°C in concentrations at least 1000 times higher than could be expected from measurements of the natural ice nuclei in the cloud environment. Until these measurements, it has been assumed that there is always a shortage of natural nuclei which can initiate freezing at a temperature just below freezing (0° to -15°C). It is in this temperature range that any artificially introduced nuclei can then alter the natural processes in the cloud. These observations, first of all, raise the important question as to what is the cloud mechanism which produces this multiplication of ice crystals, and secondly, bring to attention the important consideration that cloud seeding, in clouds where warm glaciation has occurred, may produce just the opposite of the desired effect; i.e., if glaciation has already started naturally, artificial seeding could conceivably reduce rather than increase the number of crystals that can grow large enough to produce raindrops because of the competition of a larger number of ice crystals for available liquid water.

Another portion of the program, having direct application to the underwater propagation of acoustic energy, has been testing a technique to determine the amount of dissolved gases which are secreted and vented by organisms associated with the Deep Acoustic Scattering Layer. Using an extremely sensitive gas chromatographic method, which was developed by NRL scientists to determine low-molecular-weight hydrocarbons and carbon monoxide in natural waters and in the atmosphere, the researchers have found interesting and consistent results.

Measurements of methane (CH_4) and carbon monoxide (CO) were made in the atmosphere and in the surface waters of the Potomac River, Chesapeake Bay, and Atlantic Ocean on a cruise in June 1968. The CH_4 concentration in the water generally tended to decrease as the ocean was approached, the highest concentrations being in the Washington area. In the open ocean, the CH_4 appeared to be in equilibrium with that found in the air. Except in the Washington area, air concentrations of CH_4 were remarkably constant with an average value of $1.24 \pm .03$ parts per million. Conversely, CO concentrations in the ocean were higher than those found in the river or bay. The ratio of measured CO in the near-surface ocean waters to the equilibrium amount, calculated from the measured partial pressure of CO in the atmosphere, was consistently greater than unity; that is, the direction of CO transport appears to be from the ocean into the air. The lowest concentration of CO found in the air was 75 parts per billion, in the vicinity of the Eastern Bahama Islands.

The Laboratory's ocean technology efforts research, develop, and apply specialized equipment, instrumentation, and techniques for conducting ocean and ocean-floor operations, and evolve operational technology for advanced systems. Typical of this latter effort is the fully instrumented "fish," bearing special cameras, lights, magnetometers, and other detection instrumentation which was developed at NRL and used successfully to locate both the sunken submarine U.S.S. Thresher and the nuclear device which had been lost in the Atlantic off the coast of Spain. Recent operations centered on a search for the submarine U.S.S. Scorpion proved highly successful when, on Oct. 30, 1968, NRL scientists aboard the Laboratory's ship U.S.S. Mizar located and photographed the shattered hull.

One of the major goals of the Laboratory's ocean materials research program is to advance the development of nondestructive, ultrasonic inspection techniques so that they will be 100 percent effective for the detection, classification, and interpretation of flaws in fabricated structures. While these techniques are quite useful as they are, there is still need for perfecting them further, particularly for interpreting the reaction between ultrasonic beams and the flaws in an object. For this reason it is necessary to know precisely the geometry of the beam, which is determined largely by the performance of the transducer.

To visualize the performance of these transducers, scientists at NRL have adapted a schlieren photographic technique to observe the radiated sound beam in either a liquid or a transparent solid. Most notable of the adaptations is the use of an electronic image enhancement system, which produces sharp pictures of the ultrasonic pulses or beams under study. This system has great versatility. By the adjustment of the camera, the scientist may scan small portions of the sound field and hence obtain a high magnification of the phenomena on the television monitor. Not only the spatial distribution of the radiation itself but also the reaction with idealized flaws interposed in the path of the beam can be shown graphically. The use of a high-intensity, short-duration pulsed laser, presently being incorporated in the system, should further increase the photographic resolution of the ultrasonic pulses under study. The possibility of making holograms should also be very revealing in the study of the complete structure of the ultrasonic pulses.

Most of the experimental work done thus far with the schlieren system has been qualitative in nature. An interesting series of photographs taken recently shows the existence of certain wave modes which were predicted by theory but had not previously been isolated under the usual pulse-echo techniques. Many other phenomena have been observed, and much general information has been categorized concerning the ultrasonic transducer beam patterns as well as their characteristics during reflection, refraction, diffraction, and change of wave mode. Not only does the schlieren system appear to be an effective method for studying certain transducer parameters, but it also promises to be a valuable aid in the interpretation and classification of ultrasonic flaw signatures (echoes).

PLANS AND TRENDS

Electronics

New capabilities in communication and navigation techniques will be investigated and exploited. Centralized electronic control (CEC) and centralized time and frequency control (CTFC), both of which are pivotal for increasing the reliability, quality, and optimization of conventional communications, will be expanded and applied to the enhancement of secure communications and "unconventional" communications techniques.

Electromagnetic wave propagation research, commonly done by theory and field experiments, will be approached using scaled laboratory facilities in which control of variables is both known and precise. Millimeter wave generation, propagation, and detection phenomena are planned for study and development. Electron devices ranging from microminiaturized solid state units such as multidiode arrays to large high-power traveling wave tubes are the keys to new-generation radars, IFF systems, computers, etc. Their improvement and use promise to be a large portion of the electronics program.

Extension of radar detection and identification distances will be sought through development of improved techniques and equipment. Studies of the ionosphere, radar measurements of satellites and ballistic missiles, and development of signal processing theory are planned as part of the program.

Defensive electronic warfare development will concentrate on intercept techniques, on signal processing, and on deception techniques. Electromagnetic radiation control is a prime interest of this program and will continue to be developed in the future.

Materials

By means of a newly organized Central Materials Research Staff, the wide variety of materials preparation, analysis, and characterization facilities of the Laboratory will be coordinated to provide a greater availability of these resources to the entire Laboratory research community.

The Laboratory will continue to be concerned with surface chemistry, polymer chemistry, energy conversion, habitability and life support in closed systems, and corrosion. In the realms of surface and polymer chemistry, efforts will be directed at interfacial phenomena in fiber-reinforced plastics, at coupling agents to promote adhesion and increase water-immersion resistance, at improved lubricants, and at mechanisms whereby thin organic films and water foams decrease evaporation of fuels and organic solvents. Electrochemical energy-conversion research will be expanded to include additional work on fuel cells, with special emphasis on molten salt systems and on the catalytic activity of transition metals for fuel cell electrodes in high-purity alkaline solution. The hazards of fires to personnel, particularly in enclosed or poorly ventilated spaces, has stimulated increased study of the role of oxygen on flammability and the nature of combustion products in relation to the properties of the combustibles. Corrosion studies encompass a broad spectrum of investigations including oxide films, the electrochemistry of corrosion and passivity, and the action of corrosion inhibitors. In addition, a new "core" research program on ceramic materials will be initiated to complement existing specific applied ceramics research projects. An expanded program of laser-directed chemical spectroscopy and synthesis will be undertaken to add a new chemical dimension to the Laboratory's very extensive program of solid and gas laser research.

Solid state research will continue to emphasize the determination of energy band structures, which are basic to the understanding of many important properties of solids. Studies of magneto-optical effects in semiconductors and other solids, of excited states in inorganic crystals using fast electronic techniques, and of properties of magnetically interesting materials such as ferrites, antiferromagnets and high-field superconductors will be pursued.

The methodology of molecular and crystal structure analysis by diffraction techniques, developed over many years, will be further advanced and applied to challenging, unsolved problems and more complex structures. Neutron diffraction, in particular, will be coupled with other work in the recently established basic research program on the glassy state. Drawing heavily on experience with optical properties and radiation effects in crystalline solids, the glass science program aims at a fundamental understanding of nonperiodic, or amorphous, solids. It will be vigorously prosecuted and correlated with related, more applied programs on the mechanical and surface properties of glass.

Radiation effects are of undisputed theoretical and practical importance and will continue to be actively investigated. Under the Transient Radiation Effects on Electronics (TREE) program recently formalized at NRL, work will be closely coordinated with the Electronics Area, and a variety of materials including semiconductors, lasers, crystal oscillators, and solar cells will be studied. The radiation-effects principles developed in work with simple crystals are being extended to more complex materials, specifically the ammonium salts. These salts resemble the simple alkali halides and provide a useful bridge between the inorganic and organic compounds via the substitution of organic radicals for hydrogen.

Two other new research efforts recently begun and being actively pursued are nonlinear optics, a natural consequence of the early and continued laser research effort, and high pressure research, which provides a unique means of reversibly varying interatomic spacings in solids and studying the effects on mechanical, electrical, and thermodynamic properties.

Investigations of metallurgical multiphase structures at microscopic and ultramicroscopic levels will continue in order to obtain basic information on crystal flow and microcrack mechanics. Advanced techniques such as microsolution chemistry, electron fractography, and transmission electron microscopy are utilized in work directed toward an understanding of the influence of metallurgical structure on strength, ductility, and sensitivity to strength-degrading corrosive environments. A leading technical and administrative role will continue to be exercised in the major DoD-sponsored academic-industrial cooperative research program on stress-corrosion cracking initiated within the past few years.

Research investigations of super alloys and composites are in progress, motivated by problems of decreasing oxidation resistance and strength in metals with increasing temperature. The stability of matrix and aligned phase at high temperatures is being investigated in eutectic materials where natural phase alignment occurs near eutectic temperatures. Theoretical and experimental work is planned on phase alignment and interphase boundaries during polyphase solidification. This work will be coordinated with that of other composite materials groups at NRL.

Theoretical treatments are being extended by use of many-body analysis methods to include important electron-electron interactions not included in previous models.

General Sciences

Research into ionospheric fluctuations and solar activity, such as flares, magnetic disturbances, and particle bursts, will be continued and used to augment electronic research and development in the fields of navigation, communication, and over-the-horizon radar.

From studies of quasars, supernovae, stellar evolution, particle acceleration, magnetohydrodynamics, and plasma instabilities, Laboratory scientists expect to develop new concepts of energy and energy sources. Elimination of the need for nuclear fuels through substitution of high-energy beams is a probable result of these efforts.

In the low-light-level or "night vision" arena, NRL's efforts will be concentrated on the applications of lasers, on the development of infrared devices and converters, and on the upgrading of existing low-light-level television systems.

A matter of serious concern is the fact that an enemy might surreptitiously deliver a nuclear device to a selected site within the United States for explosion at some prearranged moment. This situation has become increasingly dangerous as nuclear weapon technology has improved. Programs in which the Laboratory is either involved or in which it expects to become involved fall roughly into the following categories:

1. The battlefield identification of nuclear weapons;

2. The development of instrumentation for determining the radiation harzard at a battlefield site immediately after a nuclear detonation;

3. The development of instrumentation in support of efforts to limit the spread of nuclear weapons;

4. The development of techniques for preventing nuclear materials, intended for peaceful use in scientific research or in the production of power, from being diverted into the production of weapons.

Laboratory astrophysical research plans include the incorporation of automatic data processing in the analysis of spectra generated in the Laboratory's theta-pinch device while simulating solar conditions. An extension of the theoretical spectral analysis, an investigation of other laboratory plasma sources, and an expansion of the effort in understanding mechanisms and rates involved in the excitation of energy levels in atoms and ions by collisions are planned.

In order to design high-current electron and ion accelerators, there is a need for the development of intense electrostatic and magnetostatic fields for focusing. The central problem, as in controlled fusion research, is stability. The mathematical and technological advances required in both fields are complementary. The effort in the next few years will be directed toward a basic understanding of extremely high electron flow and of the control, focusing, and stabilization of such flows. The Sozotron will be used to study electron storage of space-charge limited flow in a ring at powers of one billion watts (1 Mev at 1000 amperes) and one hundred billion watts (100 Mev at 1000 amperes).

Oceanology

Long-range goals for the acoustics effort call for heavy involvement in a deep-water/shallow-water, long-range surveillance program. This will require that specific research, such as that in acoustic signal processing and in acoustic propagation, be largely, if not wholly, oriented toward surveillance. Involvement in an acoustic warfare program will follow as a natural consequence.

Future directions of ocean science research at NRL will point toward developing a greater capability for satisfying the Navy's requirements in the ocean, especially in those areas of ocean science not emphasized by other Navy laboratories. These capabilities will include a more sensitive determination of chemical speciation in the oceans by various methods including gas chromatography, activation analysis, and electrochemistry for correlation with ocean physical parameters and for use in the development of more reliable search and surveillance techniques. The program in biodeterioration and marine corrosion will seek to provide the Navy with basic biological and biochemical knowledge needed to minimize these two processes which are so deleterious to the efficiency and economy of the Fleet. Physical oceanography and atmospheric physics studies will develop new knowledge and techniques of evaluating ocean and atmospheric dynamics, air-sea interactions, the natural effects of the atmosphere, and the effects of the passage of a submarine on the ocean surface and at depth. The topography and structure of the ocean bottom will be subjected to intensive study to develop new geophysical techniques to evaluate important microfeatures affecting sound propagation, navigation, search, and surveillance. Benefits deriving from this ocean science program will accrue in the form of increased knowledge and techniques applicable to the solution of important national problems such as air and water pollution, mineral exploration, and conservation of ocean resources.

In support of the Navy's Deep Submergence Rescue Vehicle and Deep Submergence Systems Project, new high-yield steels and titanium alloys, in thicknesses up to five inches, will be characterized by fracture mechanics methods for their resistance to and tolerance of cracking. Research on bulk glass for structural uses will continue. The fracturing aspects of glass-reinforced plastics will be correlated with resin type and method of manufacture of the structural element.

The advancement of flotation materials such as syntactic foams and nonmetallic flotation spheres has been aided, from a rather basic standpoint, through NRL's determination of the ideal packing arrangement and ideal relative sizes of mixed spheres to be embedded in a matrix and through the design of a sectional sphere of aluminium oxide. The design, fabrication, and test of mosaic ceramic spheres for use at 20,000-foot depths and in any size is planned. Chemically strengthened glass spheres of small diameter and of uniform size will be acquired for future application in advanced flotation bodies (coarse, but ideal, form). This is new and more advanced in concept than any previous or current effort on flotation; nevertheless, it is one of the most critical and pressing unsolved problems.

In collaboration with the acoustics and solid state interests, an effort to upgrade the reliability, shock resistance, and power handling capacity of sonar arrays will be effected through failure mechanics research on transducer ceramics.

Extension of the schlieren work will be done to improve the technology of flaw detection by ultrasonics, and a new effort will be initiated whereby the method for measuring residual stress in strengthened glasses will be developed.

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13. ABSTRACT

For over forty-five years the Naval Research Laboratory, through its scientists and engineers, has been anticipating and serving the needs of the U. S. Navy. Situated within the District of Columbia, the Laboratory today enjoys easy access to and contact with the central offices of all the governmental departments, and exerts a scientific influence well beyond the usually considered naval sphere of influence.

The scientific program is administratively divided into four Areas: Electronics, Materials, General Sciences and Oceanology; however, these Areas are not mutually exclusive—a quality which has allowed the Laboratory's scientific personnel to develop and apply their expertise along lines most appropriate to the Navy's interests, while maintaining a flexibility suitable for the application of their knowledge to nonmilitary problems.

Representative programs and accomplishments are discussed.

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